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Air and Pollutant Movement in a Building Can Be Evaluated Using CO as a Surrogate

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16. ABSTRACT The paper discusses tracer tests conducted to determine how indoor conditions may affect pollutant levels, prior to initiating a study of the indoor use of aerosol products. (NOTE: Aerosol product use indoors can cause elevated concentrations of vapor-phase organic compounds.) Carbon monoxide (CO) was chosen to represent gas-phase emissions from aerosol products. CO is easy to monitor over a range of 0-200 ppm, and background levels expected in indoor environments are quite low (<1-3 ppm). CO was released in the bathroom of a test house, and CO distribution throughout the house was followed under several scenarios, including: a bathroom vent fan on/off, the furnace fan on/off, doors open/closed, and windows open/closed. Because of the concentration of CO used, a safety plan was in effect during all tests. The ability to use CO as a surrogate was evaluated by using a commercially available home spot remover containing perchloroethylene (perc). The product was used per package directions and released in the same location and conditions used in the CO tests. The distribution of perc was followed using gas chromatography. The results of the air movement study and the evaluation of how well CO can serve as a surrogate are presented.

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Residential Buildings	Stationary Sources	13M
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Carbon Monoxide	Air Movement	07B
Organic Compounds	Perchloroethylene	07C
Vapors		
Chlorine Organic Compounds		

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AIR AND POLLUTANT MOVEMENT IN BUILDINGS CAN BE EVALUATED USING CO AS A SURROGATE

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ABSTRACT

Aerosol product use indoors has the potential to cause elevated concentrations of vapor phase organic compounds. Prior to initiating a study of the indoor use of aerosol products, tracer tests were conducted to determine how indoor conditions may affect the pollutant levels.

Carbon monoxide (CO) was chosen to represent gas phase emissions from aerosol products. CO is easy to monitor over a range of 0-200 ppm, and the background levels expected in indoor environments are quite low (<1-3 ppm). CO was released in the bathroom of a test house and the distribution of CO throughout the house was followed under several scenarios, including: a bathroom vent fan on/off, the furnace fan on/off, doors opened/closed, and windows opened/closed. A safety plan was in effect during all tests due to the concentration of CO used.

The ability to use CO as a surrogate was evaluated by using a commercially available home spot remover containing perchloroethylene (perc). The product was used per package directions and released in the same location and conditions used in the CO tests. The distribution of perc was followed using gas chromatography.

The results of the air movement study and the evaluation of how well CO can serve as a surrogate are presented.

INTRODUCTION

The use of aerosol can products may be a major source of organic chemical emissions in the house at any one time. The chemicals in these products are diverse and require several sampling and analytical techniques to follow dispersion and decay patterns in a house. For example a hair spray may have a wide mixture of organics that would require sampling by sorbent tubes and analysis by gas chromatography (GC) with flame ionization detector (FID) or mass spectroscopy (MS). Several sampling times and locations throughout the house are necessary for determining the dispersion and decay patterns. With the variety of aerosol products on the market, it would be expensive to perform dispersion and decay patterns for all of them. However, if an inexpensive method could be identified that would permit the rapid measurement of the decay and dispersion patterns of a house, one could possibly apply this information, with modeling, to many of the aerosol products. Other factors would be required such as air exchange rates and sinks to run an indoor air model. One possible surrogate would be a tracer gas. The

EPA Indoor Air Test House is well suited for this type of research. The use of CO as a tracer gas can be evaluated in a building with no occupants. CO can be measured by continuous monitors with several sampling locations in the house.

EXPERIMENTAL

The EPA Indoor Air Test House was used in this study. The details of the house have been reported earlier (1). The emission source release and sample collection locations used in this study are shown in the house diagram (Figure 1).

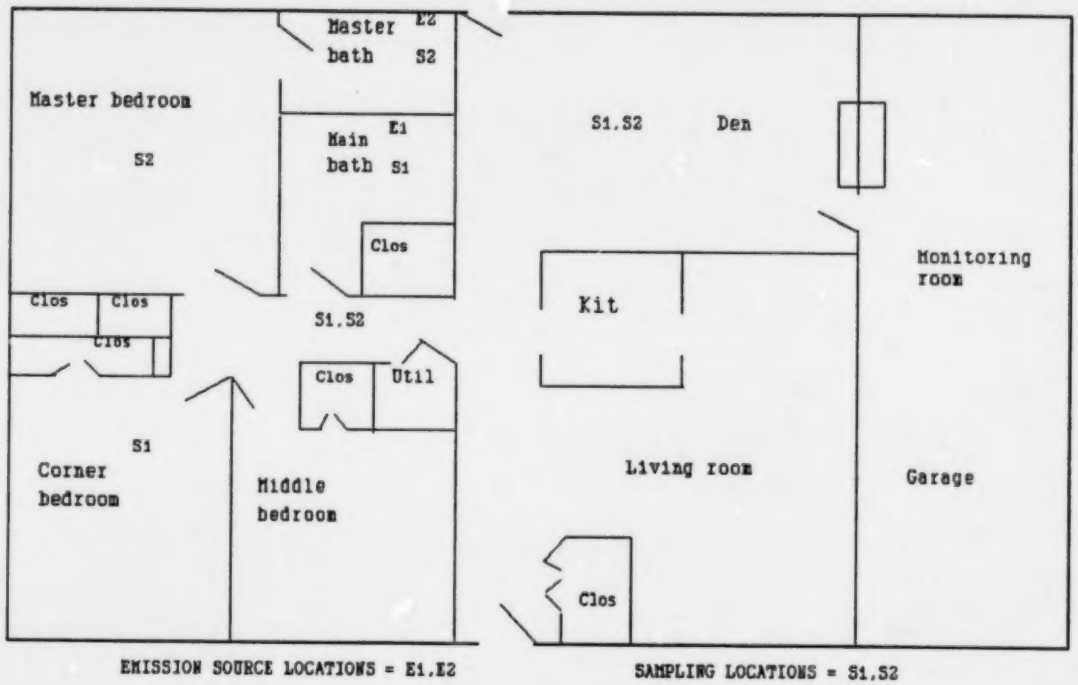

FIGURE 1. TEST HOUSE DIAGRAM

One of the bathrooms was used as the emission source site in each of the tests. When the main bathroom was the emission source site (E1), the sampling sites (S1) were the main bathroom, hall, corner bedroom, and den. When the master bathroom was the emission source site (E2), the sampling locations (S2) were the master bathroom, master bedroom, hall, and den. In all CO tests, a single burst of CO was released at the source site and then monitored sequentially at the sampling sites with a 15 minute interval between samplings at each location. The monitor was a Model 48 Thermo Electron instrument that has a range of 0-200 ppm. The variables of each test were - the bath fan on/off (main bath), window opened/closed (master bath), the door to the bath opened/closed, and the heating/air conditioning (HAC) fan on/off. When the window was open, it was 5 cm (2 in.) and when the HAC fan was on, it was continuous with the rest of the system operating in the normal operating mode with a set point of 20°C. All other interior doors were open. The CO was monitored until it reached background levels that were between 0 and 4 ppm.

The aerosol spray product was a spot remover containing 25% perchloroethylene (perc), with the remainder composed of 1,1,1-trichloroethane and propellant. A sampling strategy for perc from the aerosol spot remover was developed using an Indoor Air Quality (IAQ) model (2) and the CO data. The IAQ model incorporated sink effects from previous work (3) for perc in the house. The model predictions for CO were in good agreement when there was no sink present. Based on these results, the sampling locations and frequency for the spot remover tests were determined. The analysis of perc was by collection in glass bulbs followed by gas chromatography/electron capture (GC/EC). The details of the GC/EC procedure are given in reference 3. The spot remover was sprayed on a piece of wool blend material. The weight of the material before and after the experiment plus the weight of the spray can before and after provided the total amount of material released per test.

RESULTS

The results of the CO tests in the main and master bathrooms are given in Tables 1 and 2, respectively. The HAC system is the most significant of the parameters tested: with the bathroom door open it distributes the pollutant evenly through the house in a short period of time. With the door closed and the HAC on, the pollutant moves from the bathroom more slowly and the rest of the house builds to a lower level and decays slower. The best method for removing pollutants from the bathroom without moving them to the rest of the house was by turning the bath fan on, closing the bathroom door, and leaving the HAC system off. More then 99% of the CO was removed from the bathroom within 2 hours of release with the lowest levels elsewhere in the house. The bath vent fan removed about 50 m^3/h of air from the house.

A can of the aerosol spot remover was evaluated for the ability to provide an even spray by weight over its lifetime. After the first 2 minutes and for about 60 minutes the rate of output was constant. Therefore, each new can of spot remover was initially sprayed for 5 minutes outdoors prior to testing, and the can was not used for testing after 40 minutes of spraying.

Four tests were run using the spot remover as the source. They were selected based on the CO results that would best demonstrate the ability of the IAQ model to predict perc concentrations within the house. The four tests are outlined in Table 3.

When the spot remover was released in the main bathroom with the door open, the level of perc was high initially and low in the rest of the house. The levels dropped fast in the bathroom and by 2 hours after release the whole house was at the same concentration. At this point, the levels were about 12% (8-18%) of the original bathroom concentration. The highest concentration in the rest of the house for Test 1 (the amount sprayed was closest to recommended amount) was 550 ug/m^3 after 2 hours. Detectable amounts were still present 4 days later (3-5 ug/m^3).

Table 1. Tests In The Main Bathroom

Test Number	01	02	03	04	05	06
HAC System	on	off	on	off	on	off
Bath Door	closed	open	open	closed	closed	closed
Bath Fan	on	off	off	on	off	off
CO Volume (L)	59.0	65.1	56.6	59.1	47.4	60.0
Maximum CO Concentrations (ppm)						
Main Bathroom	>200	>200	176	>200	>200	>200
Hall	61	>200	121	6.1	174	50
Corner Bedroom	62	200	117	5.5	97	52
Den	62	172	116	2.9	80	43
CO After 10 Hours						
Main Bathroom	4.4	8.2	4.1	0.5	6.0	68
Hall	4.1	8.2	4.1	0.6	5.8	14
Corner Bedroom	4.1	8.2	4.1	0.8	5.8	15
Den	4.0	8.2	4.0	0.6	5.4	13
Temperatures (°C)						
Indoor Average	15.7	11.3	21.4	12.5	22.0	23.1
Outdoor Average	8.4	6.8	3.2	4.2	19.1	22.4
Air Exchange Rate* (h^{-1})	0.30	0.34	0.50	0.34	0.36	N/A

* Based on CO data in the den area

When the main bathroom door was closed and the bath fan was operating, the perc concentration in the bathroom dropped to 10% of the original within 2 hours and was not detectable after 17 hours. The concentration in the rest of the house never exceeded 0.1% of the original bathroom concentration.

CONCLUSIONS

A spot remover used in the bathroom under normal house conditions, door open, HAC system operating, and the bath fan off, can lead to high levels of perc in the house for several hours and not be reduced to background for up to 4 days. With the door closed, the bathroom fan turned on, and the HAC system turned off, the rest of the house has only 1% of the concentration of perc as under other conditions. It also is below detection limits in less than 1 day.

The model predictions for the concentrations of perc and the decay rate in the test house based on the CO distribution and decay patterns when corrected for the sink effect of materials in the house were good. This indicates that CO may be a surrogate for the actual material sprayed if the air exchange rate and material sink effects are known.

Table 2. Tests in Master Bathroom

Test Number	07	08	09	10	11	12
HAC System	on	off	on	off	on	on
Bath Door	closed	closed	open	open	closed	open
Bath Window	closed	closed	open	closed	open	closed
CO Volume (L)	60.0	58.3	56.6	59.4	56.6	53.5
Maximum CO Concentrations (ppm)						
Master Bathroom	>200	>200	200	200	>200	>200
Master Bedroom	200	122	200	177	113	>200
Hall	155	68	200	200	70	200
Den	97	46	139	147	54	124
CO After 10 Hours						
Master Bathroom	8.9	7.9	3.8	5.4	10	15
Master Bedroom	8.6	15	3.9	5.5	11	16
Hall	8.6	15	4.0	5.4	11	16
Den	8.2	14	4.3	5.3	10	16
Temperatures (°C)						
Indoor Average	21.1	21.7	20.5	16.7	21.7	21.8
Outdoor Average	19.0	20.0	12.7	7.3	25.9	24.0
Air Exchange Rate* (h^{-1})	0.38	0.35	0.42	0.39	0.25	0.21

* Based on CO data in the den area

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2. Sparks LE (1988) Indoor Air Quality Model Version 1.0, EPA-600/8-88-097a (NTIS PB89-133607).

3. Tichenor BA, Sparks LE, Jackson MD (1988) Evaluation of Perchloroethylene Emissions from Dry Cleaned Fabrics. EPA-600/2-88-061 (NTIS PB89-118681).

Table 3. Summary of Spot Remover Tests

Test Number	1	2	3	4
Location	main bath	main bath	main bath	main bath
HAC System	on	off	on	on*
HAC Fan	continuous	off	continuous	auto
Bath Door	open	closed	open	open
Bath Fan	off	on	off	off
Spot Remover Sprayed (g)	1.2	3.0	9.9	7.6
Maximum Perc (ug/m^3)				
Measured				
Bathroom	4042	29802	55308	24489
Living Room	744	22.8	4401	3653
Model Prediction**				
Bathroom	4500	31000	56420	25400
Living Room	790	30	4300	3700
Perc Conc. (After 10 hours)				
Measured				
Bathroom	130	7.3	765	717
Living Room	126	5.2	800	827
Model Prediction				
Bathroom	140	8.0	750	725
Living Room	140	6.0	745	725
Maximum Perc (Normalized***, $ug/m^3/g$)				
Bathroom	3368	9934	5587	3222
Living Room	620	7.6	445	481
Perc Conc. (Normalized after 10 hours)				
Bathroom	108	2.4	77	94
Living Room	105	1.7	81	109
Temperature (°C)				
Indoor Avg.	21.3	22.7	21.8	21.8
Outdoor Avg.	20.7	21.1	21.7	23.0
Air Exchange Rate (h^{-1})	0.23	0.31	N/A	0.23

* HAC system was off for the first 32 minutes after spraying.
**Model maximum is at time corresponding to measured maximum.
*** Normalized Conc. = Conc./g of spot remover sprayed.